

OLD AND YOUNG CORONAE ON VENUS; COMBINING REGIONAL AND GLOBAL STUDIES TO CONSTRAIN THERMAL EVOLUTION MODELS

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Introduction

Coronae on Venus have been studied extensively: globally they have been characterized according to morphology, tectonics and associated volcanism [1] and are generally inferred to be the result of mantle upwelling [2–7]. Previous studies based on impact crater densities at coronae [8–10] and geological syntheses [11] suggest a global stratigraphy for Venus in which coronae are relatively young features. However, recent mapping [*e.g.*, 12] indicates that regionally a significant fraction of coronae have formation onset ages comparable to the ages of regional plains, and that more detailed models are required to explain the the long and complex evolution of individual coronae. The question of the duration of corona formation on Venus since the last global resurfacing event (GRE) has an important bearing on thermal evolution models and the style of mantle convection.

We attempt to reconcile these apparently conflicting global and local perspectives by combining a regional geological study of coronae at E. Eistla Regio and results from other recent mapping [*e.g.*, 12] with a revised global study of impact crater densities at coronae [13]. We integrate our results with estimates of lithospheric thickness from topographic flexure at coronae [14] and gravity / topography admittance to develop firmer constraints on thermal evolution models.

Geology of E. Eistla Regio Coronae

E. Eistla Regio (30°–60°E, 5°–25°N) was mapped at the scale of the C1-MIDR SAR images, with the aid of F-MIDRs and topography. Mapping concentrated on six major coronae in the region. The simplified geologic history of eastern Eistla Regio consists of the following: tessera formation, emplacement of regional plains and formation of two “old” corona, (C1, C2), regional deformation, formation of four major “young” coronae

(C3–C6) and volcanism from intermediate-sized volcanoes, and the formation of a rift zone (possible new corona). There are significant overlaps in timing among many of these events.

Neither the relative ages of C1 and C2, nor the relationship between them and regional plains volcanism could be ascertained. However, extensive regional deformation of the plains resulting in NW-trending fractures and sinuous ridges affected these coronae. Combined with the lack of topographic relief for these coronae, this observation suggests that the age of onset of corona formation may be close to the age of regional plains emplacement. Flows from southern volcanoes and local, dark plains largely postdate the deformation, as does at least one flow from Tepev Mons. The timing of regional plains deformation and these volcanic flows relative to the formation of C3–C6 is not known.

The formation of C3–C6 was characterized by a period of radial fracturing, which mostly predated extensive volcanism both exterior to and interior to the coronae. At the western coronae (C3, C6) fracturing exterior to the coronae occurred sometime during this volcanism. The relative ages of C3–C6 are difficult to interpret, but it appears that at least one major episode of C6 (SW corona) volcanism postdated many flows from C3 (NW corona). Similarly C5 (SE corona) may be younger than C4 (NE corona). No direct relationship between the western and eastern coronae could be discerned, but indirect evidence from the distribution and morphology of flow features, the extent of tectonic deformation, and topographic relief are all consistent with the hypothesis that the western coronae are younger.

Impact Crater Density Estimates at Coronae

Our results from E. Eistla and those from other recent detailed geological studies suggest that although

many coronae on Venus are young relative to the time of the GRE, some coronae may have an initial formation age close to that of adjacent plains emplacement. This inference, combined with the observation that many coronae with associated topographic flexural signatures occur in the plains, prompts a re-examination of impact crater densities at coronae, classified by geological associations. Of the 354 coronae on Venus, 199 are classified as occurring in the plains. Using an existing database of impact craters on coronae [8] we calculate an impact crater density for plains coronae of $(1.8 \pm 0.4) \times 10^{-6} \text{km}^{-2}$, which is modified to $(1.6 \pm 0.4) \times 10^{-6} \text{km}^{-2}$ if deformed and embayed craters are excluded ($1\text{-}\sigma$ uncertainties). The latter crater density yields a mean surface age for coronae of $(0.8 \pm 0.2) \times T_g$, where T_g is the age of the last GRE as determined by the mean global impact crater density [15, 16]. Given the problems inherent to these kinds of global statistical analyses, the uncertainties associated with the impact crater densities are minimum error estimates. However, an important conclusion is that on average coronae in the plains have an age indistinguishable from that of the GRE and of the plains themselves.

Lithospheric Thickness Estimates

We focus on estimates of elastic lithospheric thickness (T_e), for plains regions in general, and, where possible, for coronae in the plains. Localized admittance spectra for E. Eistla based on recent gravity field spherical harmonic models [17] indicate dynamic support of topography at all resolvable wavelengths, consistent with the broad interpretation of C3–C6 as relatively young coronae. Admittance spectra for the plains regions are consistent with of present day dynamic support of the plains, and T_e of 20–30 km [18]. We have the further constraint from elastic plate modeling of topographic flexural signatures at plains coronae [14] that T_e in the range 12–24 km were associated with some stage of formation of plains coronae.

Synthesis

Our global and regional observations combined with other recent mapping studies lead us to the fol-

lowing conclusions. First, not all coronae on Venus are young; in contrast to coronae in chains and chasmata regions, coronae in the plains regions formed, on average, at a time shortly postdating, but not distinguishable from, the time of the last GRE. Second, both the uncertainties in ages associated with global impact crater density studies and the details of regional mapping indicate that coronae evolve over long periods of time. Thus the formation and evolution of coronae has been possible over the last 300–500 Myr, suggestive of gradual rather than catastrophic changes in the convective style of the venusian mantle since the last GRE.

Estimates of T_e of 12–24 km at plains coronae [15] combined with the average age of this class of feature constrain lithospheric thickness at, or shortly after, the last GRE. These estimates of T_e are inconsistent with models in which the GRE corresponded to recycling of the entire lithosphere. Gravity / topography admittance studies indicate present-day dynamic support of the plains and T_e of 20–30 km, thinner than those predicted by episodic models in which the venusian lithosphere has thickened solely by conductive cooling over the past 300–500 Myr [18]. Thus our results argue against catastrophic thermal evolution models for Venus, and support the hypothesis of ongoing mantle convection which has persisted since the last GRE along with secular cooling of the venusian interior.

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